

CLAIMS

What is claimed is:

- 5 1. A method of minimizing ventricular undersensing in a cardiac stimulation device capable of performing automatic capture verification, the method comprising:
- determining if a ventricular loss of capture event is possibly due to blanking period ventricular undersensing; and
- 10 if blanking period ventricular undersensing is suspected to have caused the ventricular loss of capture, adjusting one or more operating parameters to minimize the occurrence of blanking period ventricular undersensing.
- 15 2. The method of claim 1, further comprising continuously assessing a cardiac rhythm to determine if ventricular stimulation occurs following atrial stimulation.
- 20 3. The method of claim 2, wherein whenever ventricular stimulation occurs following atrial stimulation, performing ventricular capture verification.
- 25 4. The method of claim 3, wherein if ventricular loss of capture is detected, delivering a high-energy back-up stimulation pulse.
5. The method of claim 4, further comprising determining if a fusion event is suspected to have occurred.
- 30 6. The method of claim 5, wherein if a fusion event is suspected to have occurred, initiating corrective action.

7. The method of claim 6, wherein the step of initiating corrective action includes extending an AV delay setting.

5 8. The method of claim 5, wherein if a fusion event is not suspected, invoking a blanking period ventricular undersensing detection test.

9. The method of claim 8, wherein invoking the blanking period ventricular undersensing detection test includes invoking the test following
10 a number of ventricular loss of capture events.

10. The method of claim 8, wherein invoking the blanking period ventricular undersensing detection test includes invoking the test upon every ventricular loss of capture event immediately following an atrial
15 stimulation pulse.

11. The method of claim 1, wherein determining if the ventricular loss of capture event is due to blanking period ventricular undersensing includes detecting an occurrence of atrial undersensing.
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12. The method of claim 11, wherein detecting an occurrence of atrial undersensing includes switching a mode of operation to any one of: DDI or DDIR.

25 13. The method of claim 12, wherein detecting atrial undersensing is verified by ventricular sensing of an R-wave without atrial sensing of a preceding P-wave.

14. The method of claim 11, wherein if atrial undersensing
30 occurs, considering a ventricular blanking period as an originating cause of ventricular loss of capture.

15. The method of claim 11, wherein if atrial undersensing occurs, performing an automatic atrial sensitivity test to ensure regular P-wave sensing and to eliminate the possibility of atrial undersensing as an originating cause of blanking period ventricular undersensing.

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16. The method of claim 15, wherein if atrial undersensing does not occur, detecting a junctional rhythm.

10 17. The method of claim 16, wherein detecting the junction rhythm includes decreasing an atrial stimulation rate; and increasing atrial sensitivity to a maximum setting so that if atrial sensing of P-waves does not occur and ventricular sensing of R-waves does occur, the junctional rhythm is detected.

15 18. The method of claim 17, further comprising increasing a base stimulation rate if the junctional rhythm is detected to eliminate blanking period ventricular undersensing during the junctional rhythm.

20 19. The method of claim 1, further comprising performing an automatic ventricular sensitivity adjustment to eliminate ventricular undersensing as an originating cause of ventricular loss of capture.

25 20. The method of claim 1, wherein determining if the ventricular loss of capture event is due to blanking period ventricular undersensing includes detecting an occurrence of a premature ventricular contraction.

30 21. The method of claim 20, wherein detecting the occurrence of the premature ventricular contraction includes reducing a base stimulation rate; and monitoring a heart rhythm to determine if the premature ventricular contraction occurs.

22. The method of claim 21, wherein the premature ventricular contraction is confirmed if an R-wave is sensed and a preceding P-wave is not sensed.

5 23. The method of claim 20, wherein if the premature ventricular contraction occurs, considering ventricular undersensing of a premature ventricular contraction as an originating cause of ventricular loss of capture.

10 24. The method of claim 23, wherein a ventricular blanking period is shortened to reduce undersensing of premature ventricular contractions and to lessen the possibility of loss of capture due to blanking period ventricular undersensing of premature ventricular contractions.

15 25. The method of claim 24, further comprising assessing crosstalk after a ventricular blanking period has been shortened.

20 26. The method of claim 25, wherein a ventricular blanking period is lengthened if crosstalk is detected.

25 27. The method of claim 1, wherein determining if the ventricular loss of capture event is due to blanking period ventricular undersensing includes switching a mode of operation to VDD; and
decreasing a base rate to allow an assessment of the cause for the ventricular loss of capture.

30 28. The method of claim 27, further comprising assessing a heart rhythm as atrial sensing with either predominate ventricular sensing or predominate ventricular stimulation.

29. The method of claim 28, wherein if predominate ventricular sensing occurs, considering blanking period ventricular undersensing as an originating cause of ventricular loss of capture.

5 30. The method of claim 29, further comprising adjusting a base rate to reduce blanking period ventricular undersensing.

31. The method of claim 28, wherein if predominate ventricular stimulation occurs, further comprising monitoring a heart rhythm to
10 determine if premature ventricular contractions are occurring.

32. The method of claim 31, wherein if premature ventricular contractions are occurring, blanking period ventricular undersensing of premature ventricular contractions is considered the originating cause of
15 loss of ventricular capture.

33. The method of claim 32, further comprising shortening a ventricular blanking period to reduce blanking period ventricular undersensing of premature ventricular contractions.

20 34. The method of claim 33, further comprising assessing crosstalk after a ventricular blanking period has been shortened.

35. The method of claim 34, further comprising lengthening a
25 ventricular blanking period if crosstalk is detected.

36. The method of claim 28, wherein if predominate ventricular stimulation occurs at a reduced base rate, considering atrial undersensing as an originating cause of ventricular loss of capture due to blanking
30 period ventricular undersensing.

37. The method of claim 36, further comprising an automatic atrial sensitivity adjustment to ensure regular P-wave sensing and to eliminate the possibility of atrial undersensing as an originating cause of ventricular loss of capture.

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38. A cardiac stimulation device capable of performing automatic capture verification, for detecting blanking period ventricular undersensing, comprising:

- 10 a pulse generator that selectively generates stimulation pulses;
- a lead, connected to the pulse generator, that delivers the stimulation pulses to one or more cardiac chambers;
- a timing circuit that is responsive to a stimulation pulse to set a blanking period following the delivery of the stimulation pulse;
- 15 a control circuit that determines if a ventricular loss of capture event is possibly due to blanking period ventricular undersensing; and
- wherein the control circuit is operative to adjust one or more operating parameters if blanking period ventricular undersensing is suspected to have caused the ventricular loss of capture.
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39. The device of claim 38, wherein the control circuit further continuously assesses a cardiac rhythm to determine if ventricular stimulation occurs following atrial stimulation.

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40. The device of claim 39, wherein whenever ventricular stimulation occurs following atrial stimulation, the control circuit performs ventricular capture verification.

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41. The device of claim 40, wherein if ventricular loss of capture is detected, the control circuit delivers a high-energy back-up stimulation pulse.

42. The device of claim 41, wherein the control circuit further determines if a fusion event is suspected to have occurred.

5 43. The device of claim 42, wherein if a fusion event is suspected to have occurred, the control circuit initiates corrective action.

44. The device of claim 43, wherein the corrective action includes an extended AV delay setting.

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45. The device of claim 43, wherein if a fusion event is not suspected, the control circuit invokes a blanking period ventricular undersensing detection test following a number of ventricular loss of capture events.

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46. The device of claim 43, wherein if a fusion event is not suspected, the control circuit invokes a blanking period ventricular undersensing detection test upon every ventricular loss of capture event immediately following an atrial stimulation pulse.

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47. The device of claim 38, wherein the control circuit determines that the ventricular loss of capture event is due to blanking period ventricular undersensing by detecting an occurrence of atrial undersensing.

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48. The device of claim 47, wherein the control circuit detects an occurrence of atrial undersensing by switching a mode of operation to any one of: DDI or DDIR.

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49. The device of claim 47, wherein the control circuit detects an occurrence of atrial undersensing by ventricular sensing of an R-wave without atrial sensing of a preceding P-wave.

50. The method of claim 47, wherein if atrial undersensing occurs, the control circuit considers a ventricular blanking period as an originating cause of ventricular loss of capture.

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51. A cardiac stimulation device for detecting blanking period ventricular undersensing, comprising:

means for determining if a ventricular loss of capture event is possibly due to blanking period ventricular undersensing; and

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means for adjusting one or more operating parameters if blanking period ventricular undersensing is suspected to have caused the ventricular loss of capture.

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52. The device of claim 51, wherein the determining means continuously assesses a cardiac rhythm to determine if ventricular stimulation occurs following atrial stimulation.

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53. The device of claim 52, wherein whenever ventricular stimulation occurs following atrial stimulation, the determining means performs ventricular capture verification.

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54. The device of claim 53, wherein if ventricular loss of capture is detected, the determining means delivers a high-energy back-up stimulation pulse.

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55. The device of claim 54, wherein the determining means further determines if a fusion event is suspected to have occurred; wherein if a fusion event is suspected to have occurred, the control circuit initiates corrective action; wherein the corrective action includes an extended AV delay setting;

wherein if a fusion event is not suspected, the determining means invokes a blanking period ventricular undersensing detection test following a number of ventricular loss of capture events; and

5 wherein if a fusion event is not suspected, the determining means invokes a blanking period ventricular undersensing detection test upon every ventricular loss of capture event immediately following an atrial stimulation pulse.

10 56. A cardiac stimulation device capable of performing automatic capture verification, for detecting ventricular undersensing, comprising:

 means for determining if a ventricular loss of capture event is due to ventricular undersensing; and

15 means for adjusting one or more operating parameters if ventricular undersensing is suspected to have caused the ventricular loss of capture.

20 57. The device of claim 56, wherein the determining means continuously assesses a cardiac rhythm to determine if ventricular stimulation occurs at the base rate in a VDD system.

25 58. The device of claim 56, wherein whenever ventricular stimulation occurs at the programmed base rate, the determining means performs ventricular capture verification.

 59. The device of claim 56, wherein if ventricular loss of capture is detected, the determining means delivers a high-energy back-up stimulation pulse.

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60. The device of claim 57, wherein the determining means further determines if a fusion event is suspected to have occurred;

wherein if a fusion event is suspected to have occurred, the control circuit initiates corrective action;

5 wherein the corrective action includes an extended PV delay setting;

wherein if a fusion event is not suspected, the determining means invokes a ventricular undersensing detection test following a number of ventricular loss of capture events; and

10 wherein if a fusion event is not suspected, the determining means invokes a ventricular undersensing detection test upon every ventricular loss of capture event immediately following an atrial sensed event.

15 61. A method of detecting blanking period ventricular undersensing in a cardiac stimulation device, the method comprising:

determining if a ventricular loss of capture event is possibly due to blanking period ventricular undersensing;

20 if blanking period ventricular undersensing is suspected to have caused the ventricular loss of capture, adjusting one or more operating parameters to minimize the occurrence of blanking period ventricular undersensing; and

25 continuously assessing any one or more of the following cardiac rhythms: AV, AR, PV, PR, to determine if ventricular stimulation occurs following atrial stimulation.

62. The method of claim 61, wherein when ventricular stimulation occurs following an atrial pulse, performing ventricular capture verification.

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63. The method of claim 61, wherein if ventricular loss of capture is detected, delivering a high-energy back-up stimulation pulse.

64. The method of claim 63, further comprising determining if a fusion event is suspected to have occurred.

5 65. The method of claim 64, wherein if a fusion event is suspected to have occurred, initiating a corrective action.

66. The method of claim 65, wherein initiating the corrective action includes extending an AV delay setting.

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67. The method of claim 64, wherein if a fusion event is not suspected, invoking a blanking period undersensing detection test.

68. The method of claim 67, wherein invoking the blanking period undersensing detection test includes invoking the test following a number of ventricular loss of capture events.

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69. The method of claim 67, wherein invoking the blanking period undersensing detection test includes invoking the test upon every ventricular loss of capture event immediately following an atrial stimulation pulse.

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70. The method of claim 61, wherein determining if the ventricular loss of capture event is due to blanking period ventricular undersensing includes switching a mode of operation to any one of: DDI or DDIR; and

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decreasing a base rate to allow an assessment of the cause for the ventricular loss of capture.

30 71. The method of claim 70, wherein allowing the assessment of the cause for the ventricular loss of capture includes verifying the occurrence of atrial undersensing; and

if atrial undersensing occurs, considering a ventricular blanking period as an originating cause of atrial undersensing.

72. The method of claim 70, wherein if an atrial output is
5 inhibited performing an automatic atrial sensitivity test to ensure regular P-wave sensing and to eliminate the possibility of atrial undersensing as an originating cause of blanking period ventricular undersensing.

73. The method of claim 72, further comprising invoking a
10 blanking period undersensing detection test to determine the occurrence of premature ventricular contraction.